Proposal for Red Abalone Research Fishery at San Miguel Island (SMI)
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&
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I. Background

In January 2006, the California Abalone Association (CAA) began collaborating with the California Department of Fish and Game (CDFG) on the consideration of a limited red abalone fishery at San Miguel Island (SMI). These interactions led to broad scale absolute abundance red abalone surveys in 2006, 2007 and 2008 to generate an estimate of absolute abundance. Additionally, the SMI Abalone Fishery Advisory Group (AAG) was created "to provide a limited range of fully developed alternatives to CDFG for managing a potential fishery at SMI."

In 2008, during the AAG alternative development phase CDFG contracted with Dr. Yan Jiao of Virginia Tech to assess the status of the SMI red abalone population. This modeling work was reviewed in February, 2009, by a team of scientists led by Dr. Doug Butterworth. Dr. Butterworth's team provided broad recommendations for a way forward in the management of SMI abalone that included:

1) A program of experimental fishing should be considered at SMI as an initial step in pursuing the option for removals. If specific sustainability criteria are met then this might subsequently be expanded in a stepwise post moratorium process that is consistent with the Abalone Recovery and Management Plan.
2) The experimental harvest could be timed to occur during a defined period, allowing for weather and market considerations. This would ensure that concerns regarding regulatory compliance could be more readily satisfied without undue cost.
3) The Southeast Zone of SMI should remain an unfished control region that enables the detection of changes in abundance caused by environmental effects.
4) If an experimental commercial harvest is implemented, then recreational stakeholders should be provided with equitable resource access without compromising the integrity of the experimental strategy.

In December 2009, AAG stakeholders finalized four (4) different management alternatives and a final report was presented to the California Fish and Game Commission (Commission) in January 2010. This report included four (4) "key areas of agreement" foundational to re-establishing a fishery at SMI, including:

1) Use of an adjustable Total Allowable Catch (TAC) that is based on the most current stock assessment and monitoring surveys.
2) More data collection is needed to help determine the size and structure of the population, as well as provide information on recent recruitment and population increases or decreases.
3) Make refinements to the model developed by Dr. Jiao to project the population over longer time periods and with different levels of risk.
4) That more specificity is needed to implement whichever option(s) the Commission decides to consider or adopt.

A Marine Stewardship Council (MSC) pre-assessment of the commercial fishery AAG management alternative was completed in December 2009. The pre-assessment report stated that "the Red Abalone Fishery at San Miguel Island, if re-opened, could pass an MSC certification process using the standardized assessment tree and fishery assessment methods if the following issues are addressed":

1) Move forward with length-structured model, rather than an age-structured model, for this species which cannot be easily aged.
2) Further define the roles and responsibilities of a shared-management regime between CAMA and the CDFG, along with development of an assessment framework that will ensure the sustainability of a SMI fishery.
3) Work with CDFG to gather further information on how "withering syndrome" is transmitted and whether fishing poses a risk in the spread of that syndrome among and between populations.
4) Work with CDFG to develop a strategic research plan for SMI abalone.

More recently localized die-offs of abalone in Northern California have drawn attention to the need to assess and manage regional abalone populations beyond SMI. Thus there is a broader need that this proposal addresses, for a working model of how abalone populations and other spatially complex species can be locally assessed and managed throughout California.

II. <u>Purpose</u>

The California Abalone Marketing Association (CAMA), in conjunction with researchers at University of California at Santa Barbara (UCSB), propose to address the key issues surrounding local area management of the Californian red abalone (*Haliotis rufescens*) raised by the AAG and MSC pre-assessment (highlighted above), with an experimental fishery at San Miguel Island.

This experimental fishery proposal is the culmination of the six (6) years of work summarized above. It has been designed to address specific knowledge gaps on a number of issues central to developing an effective framework for adaptive fisheries management and it aims to address more general knowledge gaps about abalone stocks and Californian fisheries by:

1) Determining the resilience of the red abalone population to harvest, and determining the extent to which recruitment of emerging abalone (productivity) contributes to the level of resilience observed.
2) Developing and demonstrating Harvest Control Rules for setting local Catch Caps and size limits relative to size based Spawning Potential Ratio (SPR) reference points, which will be certifiable by the MSC.
3) Testing and refining the reference and trigger points defined in the Abalone Recovery Management Plan (ARMP), specifically those regarding Minimum Viable Population (MVP) densities, which lack a specific spatial scale.
4) Developing positive and constructive relationships between the dive fishing industry and CDFG, and a cooperative research structure with explicit mechanisms for sharing data gathering and decision making responsibilities.

This document proposes a controlled removal and monitoring experiment that measures effects in both treatment and control areas. The collaborative development and trialing through review workshops, of experimental Harvest Control Rules for adjusting experimental harvest rates, will have potential for incorporation into a future Abalone Fishery Management Plan. Additionally, the HCRs collaboratively developed through this proposal will have broad potential for incorporation into a Californian Fishery

Management Plans beyond abalone, and will be designed to be certifiable by the Marine Stewardship Council.

III. Experimental Design & Removal Levels

It is proposed to use 16 experimental sites, each one hectare in size. Eight (8) of these sites will be used as controls for the experimental treatment imposed on the other eight (8) sites. No abalone will be removed from the eight (8) control sites, which are for comparison purposes only. Three (3) experimental harvest rates, defined by 7", 7.5", and 8" size limits, will be tested.

These size limits were chosen based on their ability to preserve specific amounts of the Spawning Potential Ratio (SPR) in each plot. SPR is defined as the percentage of the unfished egg production retained in the stock when it is fished at a given level. It is commonly used in target and limit reference points in both national and international stock assessments.

The fundamental concept underlying the use of SPR in management is that a certain percentage of reproductive adults must be protected from fishing to ensure adequate recruitment of young fish to the stock in future years. Because reproductive capacity is often highly linked with size in fish and invertebrate populations, in which larger adults contribute more gametes than smaller individuals, size-based regulations can be employed to achieve a desired level of SPR. These size limits were chosen based on an analysis of the 2008 size frequency data from SMI, which indicated that 40% of the reproductive potential comes from abalones that are above 8", 60% comes from abalones that are above 7.5", and 75% comes from abalones that are above 7". By harvesting all abalones above each of these size limits in the experimental sites, the effects of preserving 25%, 40%, and 60% of SPR will be tested.

It is known that abalone are long lived, slow growing invertebrates, and thus the levels of SPR required for sustainable production is likely to be ~40-60%. However, this study is designed to answer a number of questions in addition to determining appropriate target reference points. This proposed experimental design will also allow us to measure the productivity of the stock in terms of recruits to the fishery. Recruitment of juvenile abalone is notoriously difficult to measure due to their cryptic nature and high natural mortality rates. By removing all abalone above 7" in four(4) of the treatment sites post-removal surveys will assess the number of abalones per hectare that "recruit" each year — that is, the number that grow to above the size limit and thus vulnerable to fishing over the course of a single year. The same measurements will be conducted in treatment sites with higher size limits, but given that the growth rates at these upper sizes have slowed considerably, the 7" treatment sites will provide a stronger signal.

The surveys conducted at SMI between 2006 and 2008 indicated that there is high spatial variability in density over small spatial scales. It is likely that the starting density in an area will influence the observed responses to removals. By having twice as many 7" sites (four rather than two) how starting density affects productivity can be explicitly tested by having two(2) low density sites and two(2) high density sites.

This spatial variability amongst sites and treatments as well as the multi-year time line of the study makes it difficult to estimate the projected impact in terms of total abalones removed. To do this it is assumed that there is an average density of 3,000 emergent abalone per experimental site, which is higher than gross surveyed densities within the total area of kelp bed, but consistent with density estimates adjusted to account for non-abalone habitat within the perimeter of the SMI kelp bed (Prince

& Valencia 2009). It is also assumed that, while divers will be attempting to remove all abalone above each treatment size limit, given the cryptic nature of abalone this will result in the harvest of ~ 80% of emergent abalone at or above the size limit similar to the 'catchability' measured in Australian studies. The proposed design detailed below involves a projected initial experimental removal of approximately 10,032 abalone (Table 1).

Assumptions:	
16 Experimental Areas x 1 ha with 3,000 emergent abalone/ha	3,000
80% (0.8) collecting efficiency during treatments	2,400

Treatments	# Treatments	SPR Preserved	Ab. Harvest
Controls - no harvest planned	8	100	0
7" size limit	4	25	6,240
7.5" size limit	2	40	2,640
8" size limit	2	60	1,152
	16	**Total Abalone**	**10,032**

Average wt. (lb/abalone)	3.75
Value ($/1b)	23
Total value of Harvest	$865,260

Table 1. Estimated experimental removals in the initial year of the project and their projected value.

IV. Projected Time Line

This project has a three-year timeline including reviewing workshops after the first and second years of field work. The project is structured so that the field work component could be terminated after either the first or second sampling periods if the data analysis indicates that the risk to the population has reached a level that is unacceptable to decision makers.

After the initial sampling in the first year of the project, results will be reported to CDFG and the Commission. These results will include proposed Harvest Control Rules within a decision tree designed to stabilize removals from each experimental area at levels that achieve the size-based SPR reference points consistent with the original aims of the ARMP. If the project proceeds into the second and third year these HCRs could be used by the Research Review Committee to adjust removal levels for each of the eight (8) experimental areas on the basis of the data gathered by the project. This does not mean that the overall experimental design would change; rather, within an adaptive control rule framework, there may be empirical evidence that suggests a change to the rates at which abalone should be removed within the existing framework.

The proposed experimental harvest framework will be adaptive and capable of incorporating these types of change without compromising the overall results of the experiment. As such, after the first and second years of harvest, CDFG and the Commission will be able to assess the information provided and decide whether to:

1) Allow the experiment to continue into the second year and third year of the project, or
2) Discontinue the experimental harvest and have the project results documented on the basis of either one or two experimental sampling periods.

V. Risk Management

Abalone would be removed from experimental sites (1 x 1 ha each). This is equivalent to 0.76% of the total area of abalone beds (1,048 ha) at SMI (Figure 1) as estimated by CDFG on the basis of kelp cover (2.4% of the abalone habitat of the SW quadrant of SMI).

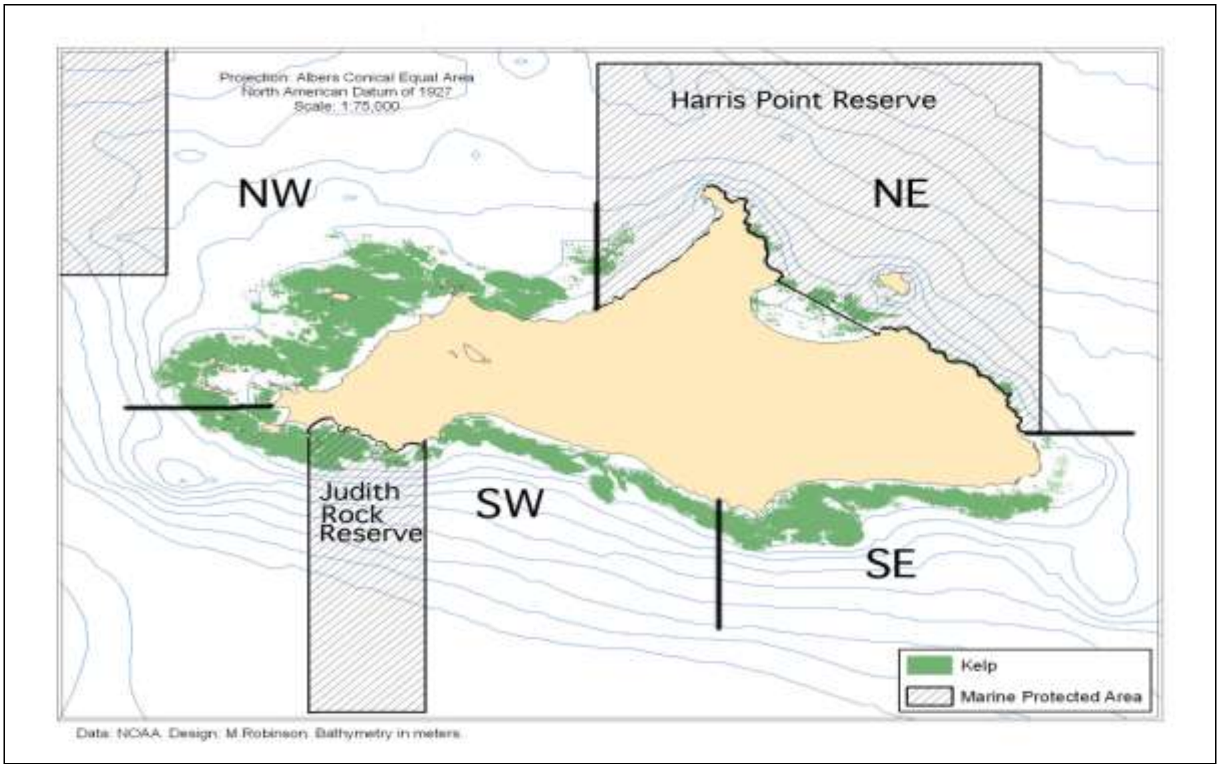

Figure 1: Chart of quadrants and Marine Protected Areas at SMI.

While there is uncertainty surrounding the exact size of the SMI population, the 2007 collaborative surveys suggested that SMI has a population of between 0.6 and 0.97 million emergent red abalone, 35-55% of which are found within the SW quadrant. Thus based on the 2007 surveys, the experiment will remove <1.5% of the total emergent abalone population at SMI and from 1.9 - 4.3% of the emergent population within the SW quadrant.

The risk to both the SMI abalone population and the broader California red abalone population is minimized because of the small scale of this experiment, in combination with the fact that the program can be stopped after each annual review. The combination of this small scale along with the data-informed review process contributes to an overall design that poses limited risk to the sustainability of red abalone populations at SMI, or more broadly in California.

These limited risks must be offset with the opportunities this project presents for developing important knowledge, techniques and models for managing California abalone stocks and other spatially complex California fish stocks.

VI. Economic Viability

Using the value of abalone estimated by Bor et al. (2010) at $23.00/lb and an average weight of harvested abalone at 3.75lb per abalone, the gross value of the experimental sample proposed is estimated at approximately $865,000 in the first year of the project (Table 1).

The project will require approximately 150 scientific diving days in the first year and approximately 75 scientific diving days per year in each of the subsequent two years. CAMA will provide scientific divers who have been trained in CDFG's abalone survey protocols. Logistics and marketing will need to be considered in scheduling field and sampling work.

The CAMA cost for each scientific diving day is estimated at $2,000 (Bor et al. 2010). This cost includes vessels, divers, deckhands, fuel, supplies, insurance, etc. On this basis the cost of the field work is estimated at approximately $300,000 (150 days @ $2,000 per day) in the initial year and approximately $150,000 in subsequent years, if the project is extended (Attachment 1).

The academic component (Attachment 2) of this project will be conducted by a post-doctoral position at UCSB under the supervision of Dr. Jeremy Prince (with fully funded UCSB overhead). The cost of this academic component is approximately $150,000 per year. If the field work was terminated at the end of the first year and scientific reporting occurred 14 months into the project, the total academic costs would be approximately $225,000. In this situation the main costs of the project would be $525,000 compared to a projected income of $865,000 suggesting a budgetary margin of $345,000 that could go towards covering project administration, unanticipated research expenses, costs of processing and handling, workshop expenses, support for CDFG liaison, and/or enforcement participation in approximately 4 days of field work during which removals will occur. Detailed project budgets will be refined prior to the project start date.

Clearly changing the number and size of abalone being sampled will change the economic viability of this proposal. As proposed the project will start with a range of sampling rates, on the basis of international experience with abalone fisheries, expected to bracket the level thought to be permanently sustainable. The project will also incorporate the experimental data into control rules within a decision tree, which a research review committee (composed of the Dr. Prince and the other scientists conducting the assessment, scientists from CDFG, and independent experts on abalone stocks) will be able to use in suggesting changes to each experimental sampling rate. If CDFG and the Commission were to accept these workshop recommendations the sampling rates proposed for year one may change over the time period of the project, with the highest sampling rates probably falling and the lowest rates possibly increasing. Note that this does not mean a change to the experimental design. Rather, within the adaptive experimental framework proposed here, the harvest level in each experimental site can be changed to reflect the level of recruitment detected in each. Should the project continue through the proposed three-year timeline it should remain self-funding if the experimental sample remains above 3,800 abalone in subsequent years (Bor et al. 2010). Below this level the project would require some source of external funding to continue, the need for this could be evaluated in the annual Research Review Committee workshops.

VII. Methods

Step 1 - Site Selection: 16 100 x 100m (1ha) experimental sites will be chosen on the south side of San Miguel Island (between Judith Rock and Crooks Point). In selecting sites, the Channel Islands National Kelp Forest Monitoring Program will be consulted to determine whether or not the KMF monitoring site at Miracle Mile should be avoided. The population data from the 2006-08 collaborative absolute abundance surveys will be used to identify survey sites in this region (between 3-20m depth) that contain both suitable abalone habitat and densities that could support a fishery (~3,000 emergent abalone per ha or higher). Since the densities measured in this area range from 3,000 to 10,000+ abalone/ha, and it will be important to select experimental sites that cover low (~3-4,000 abalone/ha), medium (~5-6,000 abalone/ha), and high (~7,000+) density areas in order to determine how density affects the resilience and productivity of the stock. This is an important step in refining reference points for use within the decision tree framework.

Step 2 - Site Stratification: All sites will initially be surveyed for habitat type. Sites will be surveyed using point intercept transects placed 10m apart (10 total across a 100m x 100m site). These transects will run perpendicular to the shore. A 100m transect tape will be run out, and a diver will swim along the transect tape recording the characteristics of each habitat type (relief, substrate, etc.), as well as the meter mark where habitat types shift from one section to the next. Divers will also qualitatively grade each habitat type based on whether they would expect to find abalone in that type. The objective of this type of survey is to create broad habitat maps of each site, and to quantify the amount of each type of habitat in each site. These maps will be used to allocate survey effort based on habitat type. It is possible that, if outside funding were available, that video could be used so that diver grading could be independently verified.

Short (10m x 1m) transect surveys will then be conducted within each habitat type. Each diver lays out a 10m transect tape and swims back along it, counting all abalone within 0.5m of the tape on either side. The actual number of transects will be determined by conducting a power analysis using the variances observed within each habitat type in the 2006-08 surveys, and will be equal for all sites. These short transects will be systematically distributed within each habitat type and will be oriented perpendicular to the shore. Data from these short 10m x 1m transects will be used to stratify all future survey efforts. This stratification is based on the abundance of abalone found within each habitat type, and more survey effort will be allocated to high density habitat types.

Step 3 - Stratified Pre-Removal Survey: Based on the habitat and short transect surveys, sites will be grouped into treatment-control pairs by habitat type and red abalone abundance estimates. This will ensure that, for each treatment site, there is a control site that is similar in habitat type and overall abalone abundance. The same total number of transects will be conducted in each site, and the number of transects necessary to detect differences between treatment and control groups will be determined using a power analysis of the data collected in Step 2. Within each site the number of transects per habitat type will be proportional to the standard deviation in abalone abundance (calculated from the data collected in Step 2). Transects will be randomly placed within each habitat type. This method of stratification allocates a higher sampling effort to more variable strata, providing a weighted mean abalone density. This lowers the total variance for each site and increases the ability to detect significant differences between treatment and control groups.

For each transect, a 20m transect tape will be laid down in a pre-determined orientation, and divers will count and record the size class (juvenile, adult, or above the size limit in each treatment site) of all abalone encountered within 1m on either side of the tape. Sizes (to the nearest millimeter) will also be recorded for a pre-specified number of abalone. The number of animals to be sized will be based the estimated densities in the treatment sites, and transects will be randomly selected for sizing in each habitat type. The diver will then swim back and record the number and size class of abalone per aggregation (>1m from their nearest neighbor) touched by the 2m wide transect. This intensive survey will yield baseline data on the size structure, relative abundance, and distribution of abalone in each habitat type before removals occur.

There is concern that the 20m x 2m transects proposed here are not comparable to previous surveys. The two surveys are designed to accomplish different things. The broad 2006-08 surveys were conducted in order to establish a baseline estimate of absolute abundance. The survey methodology proposed here is designed to: a) accurately estimate the abundance in a specific area, b) estimate the change in abundance in that area due to removals, and c) produce four (4) different types of indicators (size structure, size classes, aggregation, and abalone/ha) which can be used in monitoring the status of the population. Using a larger transect to match the 30m x 4m transects used in the 2006-08 surveys would reduce the number of independent observations (thus reducing survey power) in each site without gaining any comparability. A smaller survey unit could result in a higher observed variance. However, a retrospective analysis of the precision of survey methodologies used by CDFG since 1994 shows that there is no consistent pattern between the size of transect used and the observed coefficient of variation of abalone counts. This may be caused by the fact that, given of the fine scale of spatial variation in habitat, larger transects can often run through a number of different habitat types when randomly placed, and the survey methods previously used did not stratify based on habitat. The overall method of choosing transect locations and stratification would be different between surveys.

Step 4 - Removals: The exact number of abalone to be removed initially in each treatment will be determined by the abundance of the abalone in each area selected, the experimental size limit applied in each treatment, and the efficiency of the searching diver. Three (3) treatments based on different size limits will be tested as outlined in the table below, and each treatment will be paired with an unfished control site. Using the length frequency of surveyed abalone in 2008, and SPR models based on accepted estimates growth, reproduction and mortality, the minimum level of Spawning Potential Ratio (SPR) that will be preserved is estimated along with the proportion of the mature abalone population that will be removed. The estimates presented in Table 2 assume 100% removal above the size limit but in reality the collecting divers will most likely achieve an 80%. This means that preserved SPR levels will be around 20% higher than those estimated above, and correspondingly, the proportion collected somewhat lower.

#	Treatments	% SPR Preserved	Proportion *of Population* Collected
8	Control sites - no harvest	100	0
4	7" size limit	25	65%
2	7.5" size limit	40	55%
2	8.0" size limit	60	24%

Table 2. Experimental sites and SPR preserved.

It is proposed that the 7" size limit will initially be used at four (4) experimental sites, although it is anticipated that Harvest Control Rules developed will recommend this size limit be increased in subsequent years. The use of what is expected to be a lower than optimal size on four in the initial experimental stage is important because the impact of the removals in terms of the subsequent response of the stock will be most easily measured at high harvest rates. In terms of experimental design, with relatively limited research resources, the effect of slight treatments will be hard to detect from background noise. In the initial stage of this experiment four (4) of the strongest treatment categories are recommended in order to maximize the experimental design sensitivity to measuring the response of the fished populations.

The absolute number of abalone removed from each site will depend on the actual density of abalone in that hectare and the harvest level applied to that site. Densities will vary, but with the pre-removal surveys in hand, it is should be possible to apply the treatments across the differing sites so that the total removal cap approved by CDFG and the Commission is not exceeded. Removals will be greatest in the first year due to the biomass accumulated during the 15 year harvest moratorium. Removals in subsequent years will be smaller as determined by the experimental Harvest Control Rules that will be put in place to achieve long-term target levels of SPR.

In each treatment site, the designated number of abalone will be removed, and fishery-dependent data will be recorded, including total catch, catch-per-unit-effort (CPUE), size structure of catch, within-site GPS location of each bag of abalone, etc. **Only fully emergent abalone that can be measured and determined to be above the size limit will be removed.** All landed abalone will be immediately tagged on the boat for post-harvest tracking. A percentage of the shells will be reserved from the processed abalone to support concurrent work refining estimates of growth and size of maturity.

Logistics and marketing will need to be considered in scheduling removals. It is proposed that there will be four (4) removal days with seven (7) boats to perform Step 4 and that step will be completed at two different times (4 sites each time, one for each treatment). Exact removal locations will be will be on the south side of San Miguel Island (between Judith Rock and Crooks Point; see Figure 1).

Step 5 - First Stratified Post-Removal Survey: In order to minimize migration issues, this first set of post-removal surveys will be conducted as soon as possible (not more than 15 days) after removal is completed. Post-removal surveys will be conducted in both treatment and control sites, and will follow the protocol outlined for the pre-removal surveys. The 15 day time frame allows for post-removal surveys to be completed as soon as weather conditions allow and to minimize the impact of abalone from outside the treatment sites moving inside the treatment sites or vice-versa.

Step 6 - Second Stratified Post-Removal Survey: It is necessary to conduct a second set of surveys approximately nine (9) months after removal is completed so that data from these surveys can be available to the annual review panel. These post-removal surveys will be conducted in both treatment and control sites following the protocol outlined for the pre-removal surveys, and are needed to measure the rate at which the removed biomass has been replaced by walk-in and *in-situ* growth. It is possible to distinguish walk-ins using abalone growth rates, because all animals above the treatment size limit plus the expected growth in a single year will have moved into the plot via migration. Then this walk-in rate can be applied to the individuals between the treatment size limit and the upper bounds of projected growth to estimate the number of individuals in that size class that have grown up (in other words, the productivity of the site). This step will provide information on:

a) production in each site over the course of an annual cycle, b) the medium term effect of fishing on abalone aggregations, and c) the validity of production estimates and survey techniques prior to the following round of removals.

Steps 3 through 6 will be completed at two different times (4 sites each time, one for each treatment).

Step 7 - Data Analysis and Modeling: Data from each of the pre-removal and post-removal surveys will be used to assess the accuracy of the survey method in both predicting the abundance for each site and detecting a change in abundance. The abundance estimation accuracy can be assessed by comparing the predicted number of abalone removed (from pre-removal survey data) in each site with the actual number removed. If the number removed falls within the confidence bounds of the survey prediction, then it can be assumed that the survey methodology accurately estimates the abundance in each site. Then number of red abalone removed from the pre-removal abundance estimate will be subtracted to determine the predicted post-treatment abundance. The observed post-treatment abundance will then be compared with this prediction to measure what level of change can be detected in this survey method. Further counter-checking of survey precision will be made possible by estimates of population numbers derived using the Change-in-Ratio method. This method compares the change is size ratios of above and below size limit animals, before and after removals. The Leslie-Delury depletion technique, which correlates the decline in catch rates over multiple collection periods with the cumulative catch to estimate the number of animals remaining in the population, might also be applied in this situation, depending on how the collection regimes are organized.

There should be little change in abundance between surveys in the control sites, and this data will serve as a measure of the baseline variance in abalone movement, diver efficiency, etc. Within this context, the extent and rate at which the populations within the experimental sites rebuild following removals will be estimated. The size structure of the abalones that recruit to the population (above the size limit) in each experimental site will be analyzed. This analysis will determine the extent to which abalone have: a) grown up within the experimental area, b) grown up elsewhere, and c) “walked-in” from outside each experimental site. Together these estimates will make it possible to accurately estimate:

1) Trends in abalone biomass, number and size structure within each area.
2) The number of recruiting abalone in each area.
3) The proportion that is recruiting internally or “walking-in’ from outside areas.

The data collected will also be analyzed to:

1) To determine correlations between abundance and spatially-explicit CPUE.
2) To evaluate size-based control rules by comparing size structure of the catch to the abundance and size structure of the remaining population.
3) To create surplus production models to make predictions about long-term sustainable harvest levels.

Step 8 - Harvest Strategy Evaluation of Management Control Rules for Red Abalone: The estimates of recruitment rate and productivity produced by the field study will be used to specify a Harvest Strategy Evaluation (HSE). This model, which will simulate everything that is known about the population dynamics of red abalone at SMI as well as the data collected in this study, will be used to develop and test the rigor of control rules that are being discussed as potential basis for a future Fishery Management Plan (FMP). The decision tree framework being discussed has been applied in other fisheries and uses a size based assessment technique to stabilize population size structure, and catches, at levels that will achieve SPR targets for breeding stock conservation. Decision trees can take a number of forms, but most rely on both size-based and CPUE-based indicators, as well as trends from previous years. This proposed survey method lays the groundwork for building a data series of the indicators required for this type of harvest strategy. Because these indicators are paired with intensive surveys, this experimental fishery will be able to test the efficacy of the various indicators and establish the most informative ones for use in harvest strategy. Additionally, the fine scale data collected within this project will provide a HSE model that will enable testing the performance of the proposed decision tree via simulation for stakeholders' edification, discussion, and further development. HSE allows control rules and harvest strategies to be tested under a range of uncertainties. Decision makers will be able to see how well each potential harvest strategy attains pre-specified management objectives when deciding on the best course of action.

Step 9 – Research Review Committee Workshop: Approximately 14 months into this project a Research Review Committee workshop will be held. This workshop will involve CDFG, Commission, CAMA, and researchers with the aim of developing a shared understanding and directing further development of this approach in a way that ensures governmental requirements and objectives for a future FMP is achieved. The HSE model will be developed for use within workshops involving CDFG, Commission, CAMA, and researchers The experimental decision tree, HSE, and Harvest Control Rules will also be developed by workshop participants by adapting the approach to the scale of the eight (8) experimental sites. The Harvest Control Rules can then be used to suggest how experimental removal rates should be adjusted for years two and three of the project.

VIII. <u>Expected Outcomes</u>

A. Improved Understanding of Red Abalone Population Dynamics

A primary outcome of this experimental study will be improved knowledge of red abalone population dynamics and assessment, specifically including:

1) An estimate of the annual rate of red abalone recruitment and the rate at which populations can potentially rebuild.
2) An estimate of a sustainable level of harvest for SMI, which can be applied to any future commercial or recreation fishery that is established there.
3) A method to quantify the effect of fishing on breeding aggregations of red abalone.
4) An estimate of the cost and effectiveness of different monitoring and assessment techniques (relative abundance estimates, tracking density of different size classes, size and composition of aggregations, spatial CPUE, size-based decision rules, etc.).
5) Population models that can be used to assess future risk and determine reference points and control rules for managing any spatially complex fishery.
6) Tested Harvest Control Rules which stabilize local catch caps at target SPR levels.

B. Cooperatively Developed, Certifiable Harvest Control Rules for Setting Local Catch Caps

Perhaps the most important outcome of this project will be that the review panel will collaboratively develop and apply Harvest Control Rules and decision trees that match experimental / local catch caps with size targets based on SPR reference points. This model of Harvest Strategy can be directly applicable to future Abalone Fishery Management Plans and differing locations. It will also have general applicability to all spatially complex fisheries. The outcome of this project's collaborative processes will be a shared understanding of the Harvest Control Rules and their potential for future application within an Abalone Fishery Management Plan.

Some of the proponents of this proposal (Prince and Valencia) have recently (May 2012) received long term funding commitments from the David & Lucille Packard Foundation, on behalf of the MSC to finish publishing and establishing the technical basis of the SPR at Size Harvest Control Rules being proposed here. Prince and Valencia will also begin implementing the approach in six (6) fisheries around the world. The Packard Foundation and MSC are hoping this approach will become the new certifiable standard for assessing data-poor and spatially complex fisheries. While separate to this Packard / MSC project, this proposal would run in parallel and be informed and cross-fertilized by the related work being undertaken by Prince and Valencia. As these projects will likely converge, it can be expected that the Harvest Control Rules developed for SMI by this experiment will become compatible with MSC certification standards.

IV. References

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